# White Matter Attenuation Sequence Optimization at 7T with Applications in Multiple Sclerosis and Epilepsy

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**Introduction** Increasing image contrast and resolution is vital to early detection of abnormalities in the brain. White matter attenuation (WHAT) accomplishes this goal by suppressing the signal of white matter and enhancing the signal contrast of gray matter and cerebrospinal fluid, allowing for improved diagnosis of neural diseases. Potential applications of the WHAT sequence include depicting white matter lesions in multiple sclerosis[1] as well as identification of heterotopic gray matter in epilepsy.

**Theory** White matter attenuation is achieved with an Inversion Recovery Turbo Field Echo (IR-TFE) sequence. The acquisition parameters—shot interval and inversion time (TS and TI, respectively)—are adjusted such that center of k-space is collected when the signal from white matter is effectively zero. The sequence was simulated using the IDL (ITT Visual Information Solutions, CO). The mathematical model was adapted from Deichmann, et al.[2] Setting the right hand side of the signal equations to zero indicated that a range of possible TS/TI values can be used to achieve the WHAT condition. (Figure 1)

**Methods** Images of 5 healthy (male/female, ages 24-54) and 4 MS and 2 epileptic patients were acquired using a 7T scanner (Philips Achieva, Cleveland, OH) with a T/R head coil and 16-channel SENSE coil (NOVA Medical, MA). IRB approval and informed consent were obtained by all participants. Signal to noise ratio (SNR) per scan time was calculated to determine the best acquisition parameters for clinical usage.

**Results** Comparing the simulated signal response with measured regions of interest (ROIs) shows that the theoretical model is very well correlated to measured data (Figure 2). Voxel and acquired matrix size, together with the TS/TI parameters, were used in calculating simulated SNR/scan time as shown in Figure 3. Based on this metric, it can be determined that at TS = 3700 ms and TI = 550 ms and a spatial resolution limit of 0.35 x 0.35 x 1.4 $mm^3$, the maximum SNR per 10 minutes of scan time is achieved. The large SNR jump around 3500 ms in the graph corresponds to the point at which the scanner is unable to collect the full k-space within one TFE shot, doubling the number of shots and the scan time required to collect the full set of data. The superior tissue contrast achieved by this sequence was favored by image readers of this preliminary study. White matter lesions and heterotopic gray matter were easily identified and the depiction of cortical lesions was considered adequate. (Figures 4 and 5)

**Discussion** This sequence has been shown to be effective in epileptic and MS patients for improved detection of white matter lesions, depiction of fine vascular detail and perhaps cortical lesions. The high tissue contrast of this sequence has shown immense promise in the quest for improved, non-invasive diagnostics for neural diseases.

**References** [1]Calabrese, et al., *J. Neuro*, 2008; [2]Deichmann, et al., *NeuroImage*, 2000

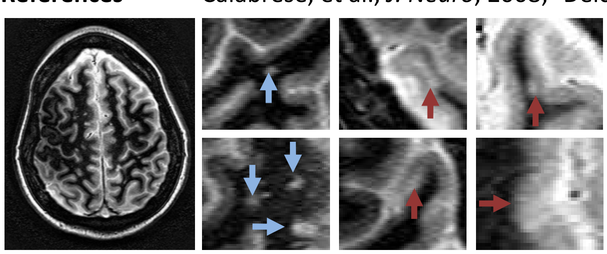

Figure 4: Whole brain WHAT image of MS patient. White matter lesions (blue arrows) and cortical lesions (red arrows) are easily identified with this sequence.

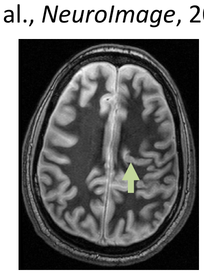

Figure 5: Heterotopic gray matter is visible in an epileptic patient (green arrow).

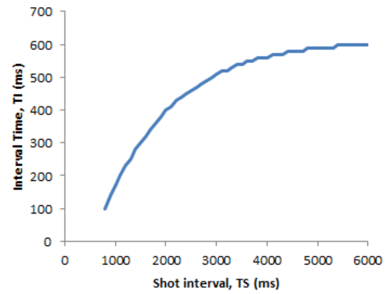


Figure 1: White matter attenuation is an IR-TFE sequence with the shot interval and the inversion time adjusted such that the white matter signal is zero when the center of k-space is being acquired. The graph indicates the TS/TI pairs at which this occurs.

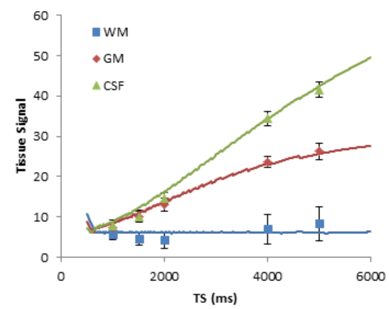


Figure 2: Graph showing the excellent correlation between the simulated signal response (line) and measured image data (markers).

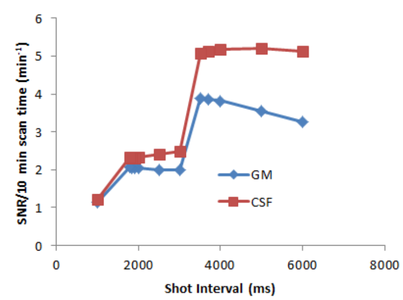


Figure 3: Simulated signal to noise ratio achievable per 10 minute scan at a resolution of 0.35 x 0.35 x 1.4 $mm^3$. Above a TS of approximately 3700 ms, the SNR/scan time plateaus, indicating that an increased scan time no longer translates into increased SNR. The large SNR jump around 3500 ms in the graph corresponds to the point at which the scanner is unable to collect the full k-space within one TFE shot, doubling the number of shots and the scan time required to collect the full set of data.